

PREPARED TESTIMONY OF  
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SCIENCE ADVISOR TO THE COUSTEAU SOCIETY  
ON CORAL REEF CONSERVATION ISSUES  
BEFORE THE SENATE COMMERCE, SCIENCE, AND TRANSPORTATION COMMITTEE  
OCEANS AND FISHERIES SUBCOMMITTEE

INTRODUCTION

Good afternoon. My name is Phil Dustan, and I am testifying on behalf of the Cousteau Society for which I serve as Science Advisor. As the new millennium approaches, it is appropriate to take stock of the health and assess the future prospects of the most fantastic undersea ecosystems ever explored by Captain Cousteau - the world's coral reefs.

The Cousteau Society is a nonprofit, membership-supported organization dedicated to the protection and improvement of the quality of life for present and future generations. Created in 1973 by Captain Jacques- Yves Cousteau, the Society has approximately 150,000 members worldwide. Cousteau teams have explored the water system throughout the world for over forty years. Their unique explorations and observations have been documented in more than forty books, four feature films, and over one hundred television documentary films that help millions of people to better understand and appreciate the fragility of life on our Water Planet. I am a Professor of Biology at the University of Charleston, SC. I am a coral reef ecologist specializing in the ecology, photophysiology, and vitality of corals and coral reef communities. Much of my work centers on detecting changes in the coral reefs of the Florida Keys. I have worked in the Florida Keys, Bahamas and throughout the Caribbean Sea, Sinai Peninsula in the Red Sea, and the Seychelles Islands, Indian Ocean. My field experience includes over 1000 scientific dives, submersible experiences, and thousands of miles at sea on scientific research cruises to most of the oceans of the world. As a young scientist, I first worked with Captain Cousteau in 1974-5 filming, writing, and editing the Mysteries of the Hidden Reefs, part of the Undersea World of Jacques Cousteau series. I also have worked on the synthetic coral reef project in the ecologically closed Biosphere2 experiment in Arizona and participated in developing the use of NASA satellites to map oceanic productivity. Finally, I am presently a principal investigator on the U.S. Environmental Protection Agency Florida Keys Coral Reef/Hardbottom Monitoring Project.

Madame Chair, Members of the Committee, thank you for providing me with this opportunity to appear today as witness before the Subcommittee on Oceans and Fisheries.

ANCIENT ECOSYSTEMS FACING MODERN PROBLEMS

Captain Jacques Cousteau opened the eyes of millions of people around the world

to the wonders of the undersea realm. He showed us that the oceans are alive. His vision and spirit of adventure took us to places never before experienced. The voyages of Calypso fed our imagination and sparked our desire to understand the nature of life beneath the sea. Some of his earliest films focused on coral reefs, the most marvelous of all underwater ecosystems.

Coral reefs are found throughout the tropical, equatorial waters of the world's oceans. They are the oldest, most complex ecosystems in the sea -- the marine equivalent of tropical rain forests in terms of ecosystem diversity and productivity. Coral reefs are a reservoir for much of the world's marine biodiversity, supply an estimated 10% of the world's fisheries, protect small island developing states from coastal erosion, and provide a strong economic base for tourism. Additionally, we are just beginning to understand the incredible potential this rich biodiversity may hold for scientific and medical advances.

Modern coral reefs evolved approximately 225 million years ago, and over this enormous span of time they have developed sophisticated ecological relationships that support such rich marine biodiversity. Reefs are built by tiny colonial organisms who compound their skeletal masses over thousands of years. Crystalline calcium carbonate is deposited by single celled animal-plants with paper thin tissues who make skeletons that withstand the strongest seas. Coral reefs are without doubt the strongest biologically built structures on the planet, and are the only naturally built ecosystems in the seas that are visible from space. Coral reefs are nature's biggest construction project.

Unfortunately, their delicate complexity makes coral reefs vulnerable to changing environmental conditions, particularly temperature, sediment, and nutrient concentrations. Ironically, the many values of coral reefs -- as a fisheries resource, for coastal protection and building materials, and more recently as tourist attractions -- now are contributing to their steady and rapid decline. Sadly, scientists and resource managers recognize that catastrophic coral reef degradation is occurring in all oceans of the world at unprecedented and alarming rates.

Anthropogenic stresses are thought to be contributing to the deterioration of coral reef ecosystems throughout the world, but most notably in the Caribbean and the western Atlantic. Growing coastal populations and related development have altered the ecological characteristics of watersheds, resulting in rivers overloaded with sediments, nutrients, and toxic chemicals. Coral reefs subjected to these conditions are showing signs of decreasing health -- coral cover is disappearing while lethal algal growth is expanding. Overfishing and the commercial harvest of reef resources have contributed to unprecedented decline

in reef diversity and ecological stability. Ironically, many reefs also are suffering from increased "eco- tourists" who cause direct, physical damage to the reefs they visit by taking home "just one souvenir." Finally, coral bleaching is widespread in every tropical sea, which scientists have linked the gradual warming of the ocean.

In addition to their intrinsic biological and esthetic values, coral reefs are important to many regions of the United States as a source of economic development, principally through tourism, but also as a foundation for many important recreational and commercial fisheries. Coral reefs also play a fundamental role in the economic structure of tropical coastal countries throughout the world, both as sources for local commercial fisheries and attractions for foreign visitors. Ultimately, coral reefs may be a vital indicator of overall oceanic health and global climate developments and may assist in our understanding of the complex relationships in our global ecosystems.

## LONG TERM SCIENTIFIC STUDY ON THE HEALTH OF THE FLORIDA KEYS CORAL REEFS

My research into coral reefs began with my graduate studies in Jamaica in 1969. In 1974, I began to investigate man's impact on coral reefs in the Florida Keys, a project funded by the Smithsonian Institution and the Harbor Branch Foundation. My direction was to investigate human impacts on coral reefs. This began the longest, continuously running study of the health and vitality of corals reefs in the Florida Keys, and in the world. My approach to the problem was hierarchical, with studies at the levels of individual corals, localized populations, and the broader ecosystem. We established a permanently marked transect study site at Carysfort Reef, the richest and most diverse reef in the Florida Keys. My research team surveyed abundance of corals, estimated their recruitment and mortality rates, and began to assess anthropogenic impacts. Today these data serve as a baseline for evaluating the degradation of a once healthy coral reef ecosystem.

My team's initial work suggested that the reef tract was changing quickly. Coral recruitment was much lower than in the West Indies, and small corals were becoming more difficult to find. Two coral diseases, Black Band Disease and White Plague were just becoming significant infectious diseases, and a third condition, algal-sediment encroachment, comprised the major agents of mortality. In the summer of 1975, we established a study site in the Dry Tortugas, ostensibly as a control site for the Florida Keys. The reefs there were in much better condition than the northern Florida Keys, as coral development there was very rich, with little or no disease.

Returning in 1982 to resurvey Carysfort Reef, I observed that in seven years coral cover and diversity had increased in the shallow areas of the reef while the deeper, fore-reef terrace had suffered significant losses (Dustan and Halas, 1987). Change in shallow water seemed driven by the destruction of the dominant stands of *Acropora palmata*, elkhorn coral. The area bore the scars of boat groundings, including pieces of propeller blades and signs of antifouling bottom paint. Cover had increased because the lush, three-dimensional habitat had been reduced to planar rubble which covered more of the bottom and smaller colonizing species were settling on open substrate. However, deeper colonies were dying from disease and sediment damage, and they no longer were being replaced by recruitment. High rates of mortality continued to be documented by other researchers in the Florida Keys between 1984 and 1991 (Porter and Meier, 1992).

In July 1984, my students and I made observations on the phenotypic condition of over 9800 corals on 19 different reefs in the Key Largo region. Sixty percent of the corals showed signs of physical or biological stress, 5-10 percent were infected with disease and about one third appeared healthy. Surprisingly, virtually all the areas we surveyed had approximately the same level of unhealthy corals.

As a control to our observations, we visited the reefs of San Salvador, Bahamas, site of Columbus' first landing in the Western Hemisphere. I was surprised to find that similar patterns of reduced coral vitality. A higher percentage of corals were considered healthy, but we also found a host of diseases, including Black Band and White Plague. Therefore, it was disturbing to observe such high percentages of "stressed" corals could be found even in waters that are remote from industrial pollution or anthropogenic nutrient loading (Dustan, 1993).

## EARLY FEDERAL RESPONSE TO THREATS FACING FLORIDA KEYS CORAL REEFS

As a result of increased scientific recognition that Florida Keys coral reefs were deteriorating, Congress passed legislation to provide protection to coral reefs and support research on the declining health of coral reef ecosystems. In 1990, the Florida Keys National Marine Sanctuary Act established the Florida Keys National Marine Sanctuary and directed the U.S. Environmental Protection Agency ("U.S. EPA") to institute a water quality assurance and protection plan for the Florida Keys, and to monitor the status and trends of the seagrasses, coral reefs and hardbottom communities and water quality.

My colleagues and I designed the U.S. EPA Coral Reef Monitoring Project ("CRMP"), to detect change in the status and trends of coral reef and hardbottom

communities of the Florida Keys. We used repetitive underwater observations and video transects to provide estimates of biodiversity, distribution, and coverage of reef corals and associated benthic organisms. Starting - in 1996, the CRMP annually sampled 160 stations at 40 sites on 32 reefs that are distributed throughout the Florida Keys. In June 1999 we added ten more stations at three sites in the Dry Tortugas.

When we began this project I felt that we might see some changes within the first five years. However, the rate of degradation has been much faster. In three years of sampling we have witnessed increases in the distribution of diseases which kill corals, increases in the number of species with diseases, and coral bleaching has become relatively common. Many of the reefs have lost species.

### PRECIPITOUSLY DECLINING HEALTH AT CARYSFORT REEF

Carysfort Reef has continued to decline. By June 1998, coral cover in the shallows had decreased to approximately 10%, and 5 to 10% in the deeper habitat zones. During a dive on Carysfort Reef in July 1998, we were unable to find a single colony of star coral, *Montastrea annularis* species complex, that was not infected with the White Plague. Large colonies (in excess of 1 meter in diameter) were rapidly being overtaken by White Plague. Since the skeletal growth rate of *M. annularis* has been measured at 5 to 10 mm/year, I estimated that these colonies are at least 100 years old (Dustan, 1975). Some colonies are at least twice this age, and White Plague kills them in less than a single year. With such rapid mortality of large colonies, coral cover may soon fall below 5% cover, and corals will cease providing any significant contribution to reef framework construction.

It is not an overstatement to suggest that this reef is entering a state of ecological collapse. Similar ecological degradation has occurred on many reefs throughout the Florida Keys, including Molasses Reef, Looe Key, and Sand Key. Carysfort, however, is the only reef where this longterm change has been documented with quantitative line transect studies. In fact, the change is so extensive that it can be detected in Landsat Thematic Mapper satellite imagery.

Interestingly, observations I made in the Dry Tortugas last month suggest that the reefs there are showing slower decline than in the Key West area. So it appears that corals in the Dry Tortugas are not stressed to the same degree as in the "mainland" Florida Keys. Coral Cover on Bird Key has decreased an estimated 20-25% as opposed to the 5-10% for Carysfort Reef. These reefs are buffered from Key West by 65 miles of ocean which may help to explain why these reefs are somewhat healthier than the Keys reefs. Although the reefs in the Dry

Tortugas are in marginally better condition, nevertheless, they are experiencing considerable decline and there is cause for serious concern.

## NESTED LEVELS OF STRESS

Based on my systematic examination of the decline of coral reefs in the Florida Keys, I have drawn several conclusions regarding root causes of the collapse of reef ecosystems. Some of the increased stresses that corals are now exposed to are simply amplifications of naturally occurring stress, and others are new within the lives of presently living corals. Many of these stresses are nested within each other and probably amplify the intensity on any single factor. Reefs in all the tropical seas are threatened by degraded ecological conditions that originate locally, regionally, and from the shores of distant continents (Bryant et. al., 1998; Hatzios et. al 1998). Remote oceanic reefs are effected by global change such as elevated ocean temperatures and increased ultraviolet light. Reefs in coastal waters are effected by these factors and additional stressors such as increased sediments, carbon, nutrients and harvesting. Coastal reefs near population centers have the increased pressures from sewage, watershed effluent, garbage dumping, and greatly increased levels of harvesting.

A significant portion of reef degradation may be related to watershed lands that have been altered from their natural state. Generally, natural terrestrial ecosystems tend to be conservative and export little in the way of nutrients, carbon, and sediments. Agriculture, urbanization, and deforestation reduce the capacity of terrestrial ecosystems to trap and retain these materials, and the rivers become overloaded with sediments, nutrients, and toxic chemicals. Simple runoff becomes an effluent that can have a significant negative influence on water quality. The addition of fertilizers, organic carbon, and urban and commercial dumping further enrich the watersheds effluent as it flows into the sea. Although concentrations may be diluted, these agents may still affect reef health. Coral reef ecosystems have evolved to be very efficient in trapping and retaining nutrients even in concentrations that, though technically beyond the level of detection, are still ecologically significant. This creates a situation in which materials from a diffuse array of sources contribute to pervasive levels of chronic stress to reefs.

In the Florida Keys, the question is frequently asked, which is the single factor mainly responsible, sediments or nutrients? It may well be that the factor is actually the accumulation of a series of nested stresses which are as local as fishing and tourism; as regional as cities, agriculture, and industry; and as global as deforestation of the rainforests, the hole in the ozone, and the greenhouse effect. Each factor compounds upon the others, and the vitality of the reef declines.

Locating the sources of increased nutrient and sediment levels and other stressors, has proved as elusive as defining the nested levels of stress. Point sources are usually known and can be controlled through permitting processes. Non-point sources are much more difficult to define. The Florida Keys are downstream from almost every source of sediment or nutrient in the Caribbean basin and Gulf of Mexico. Just upstream of the Keys, the effluent of cities, towns, and farms slowly bleeds into the sea through canals, rivers, and coastal bays. The area extends into the watershed of the Mississippi River and continues throughout the Caribbean Sea. For example, sediments from as distant as the Orinoco or Amazon Rivers have been identified on Carysfort Reef (Dustan, unpublished). Point sources, such as sewage outfalls or agricultural irrigation canals, are steady, welldefined, and easily traceable. Leaching from shallow septic tanks, urban lawns, and run-off from agricultural and deforested lands are considered non-point sources of pollution. They are widely dispersed and less consistent. Both types contribute to the hydraulic flow that pushes sediments, nutrients, and contaminants into the sea. In Florida, some of these materials wash into the sea along the west and east coasts of the peninsula, some flow through the Everglades, and others emanate from the Mississippi and lands that are farther upstream. On a larger geographical scale, the over-addition of nutrients, organic carbon, and sediments from land use practices are responsible for coastal hypoxia near river mouths and deltas. Many of these areas are defined as dead zones because the water is depleted of oxygen to the extent that it will not support aerobic metabolism (Cooper, S. and G. Brush, 1991; Malakof, 1998; Costanza et al, 1998). On still a larger scale, coastal ocean current patterns circulate coastal pollutants and their effects throughout the seas.

Corals with weakened immune systems are susceptible to disease than healthy corals. In the Florida Keys, disease is a significant source of colony mortality, and appears to be on the increase. Additionally, coral recruitment and regeneration rates are low and appear to be decreasing. Increased sedimentation will smother corals, increased nutrients in the absence of elevated herbivory will result in algal overgrowth, elevated temperatures will promote bleaching, and diseases do seem to be more prevalent in areas close to centers of human habitation. Unfortunately for the coral reefs of the Florida Keys, these stresses seem to have converged to produce a suite of multiple stressors which are pushing the reefs into a state of ecological collapse from which recovery may not be possible within a human lifetime. It is not an exaggeration to suggest that the world's coral ecosystems, through neglect, are suffering severe ecological degradation. Some suggest that, like tropical rain forests, these biomes will continue their downward spiral. Events such as the mass bleaching with subsequent mass mortality in the Maldives in May 1998, raise the question of the influences of global scale anthropogenic stress such as

global warming affecting the health of reefs. Ultimately, coral reef ecosystem health may be a sensitive indicator of overall oceanic health and changing climate, and can help to focus our attentions on preserving the ecological integrity of our global ecosystems.

## CORAL REEF CONSERVATION GRANTS

The Cousteau Society strongly supports provisions in S. 725 and S. 1253 establishing an innovative financing mechanism for coral reef conservation. The availability of these funds will help to foster innovative projects that reward entrepreneurial and creative approaches to coral reef conservation. Using federal grants to leverage coral conservation projects developed at the local level also provides an important means for involving communities and concerned citizens in this effort. To assure success, however, adequate financial resources must be authorized and appropriated.

One positive aspect of this bill is its apparent goal of putting money into the hands of "little people. Much of the research I have described was accomplished with small grants or personal funds. Independent investigator science, not big programs, has been responsible for most of the creative and insightful science done on coral reefs. Much of the current reef conservation is accomplished by similar people, not large programs. Even today, our Coral Reef Monitoring Project ("CRMP"), the largest, most precise monitoring project of its kind is done by people with a passion for their work. As large as our project is, it is still underfunded. Our institutions have cut their indirect rates, and people work for reduced wages because they love coral reefs. From my reading of the bill, it focuses on putting funds into the hands of "reef" people, not programs. Larger programs may add value to coral reef conservation efforts, if they are well-designed and implemented, however, they often become unwieldy or lose focus on the goal of enhancing direct protection or conservation actions. This bill will provide support where it is needed right now.

For example, the following initiatives could be pursued by innovative public/private grants:

- Develop and test small-scale innovative alternative sewage systems
- Encourage a reef gardening approach to care for local reefs
- Support Local conservative issues.
- Fund scientific process studies into coral health and vitality
- Fund local case studies.
- Encourage education activities
- Fund graduate student projects related to coral reef conservation
- Develop innovative boater awareness programs
- Support the installation and maintenance of mooring buoys

- Develop the mariculture of coral reef organisms for the aquarium trade

In addition, modest funding also could stimulate educational and public outreach activities, including:

- Support the development of strong and continuing broad-based educational programs at all levels to increase awareness of the impact of human activities on coral reef ecosystems.
- Increase global awareness that ultimately, coral reefs may be a vital indicator of overall oceanic health and changing climate.

I have noted that stress to coral reefs resides within a series of nested scales. As the scale increases, the magnitude of the problem increases and it becomes more difficult to ameliorate environmental pressures. The legislation before you today, S. 725 and S. 1253, represents an important step in the fight direction. Assuring the future of the nation's coral reefs will depend on our willingness to invest in protecting and maintaining their health. Proposals to address water quality such as H.R. 673, the Florida Keys Water Quality Improvement Act (sponsored by Congressman Deutsch (D-FL)), also should be considered. The Committee also should consider recommendations under consideration by the Coral Reef Task Force. Clearly, the need for additional funding over the long term to protect these resources must not cause us to shirk from our obligations. More comprehensive legislation will be needed in the future if we are assure the survival of the nation's coral reefs for the benefit of present and future generations.

## CONCLUSION

In closing I would like to say that I have painted a grim picture for the future of the reefs of the Florida Keys. It is based on my own scientific data collected since 1974. I met Captain Cousteau the same year I began my work in Florida. He shared his personal observations on the degradation of coral reefs in the Red Sea, and we talked of the changes that humans caused to reefs. Neither of us ever imagined that ecological events would progress this far so fast. However, Captain Cousteau felt that people want to protect things that they love and cherish.

The reef is a structure of ancient ecological design. Its physical morphology, its orientation to the forces of the sea, and its community structure have been tested and molded by time and natural selection. Reefs have weathered global climate shifts, plate tectonics, and dramatic sea level change. The reef community has evolved into a fully integrated marine civilization superbly adapted to a nutrient impoverished ocean. Its design for ultimate conservation of nutrients through symbioses and detailed trophic interactions has made it

vulnerable to small external perturbations. This delicate complexity makes coral reefs vulnerable to changing environmental conditions, particularly temperature, sedimentation, increased nutrient concentrations, and overharvesting. Ironically, the many values of coral reefs -- as a fisheries resource, for coastal protection and building materials, and as tourist attractions -- now are contributing to their steady and rapid decline and disruption of their biological integrity. We need to factor these realities into an approach for long-term reef conservation.

As stewards of these valuable marine resources, the United States has a responsibility to continue to take steps to conserve coral reefs within its jurisdiction. Congress has enacted important legislation to meet this challenge, and supported the establishment of marine sanctuaries to safeguard specific coral reef ecosystems. More than ever, coral reef conservation efforts are essential to raise public awareness about the importance of humanity's impact on the marine environment, before current trends become irreversible. Clearly, "business as usual" is no longer acceptable if we are to conserve these critical resources for the benefits of present and future generations. We stand on the threshold, but it is not too late to reverse the tide of destruction.

Madame Chair, members of the Committee, the legislation before you today is the first step in this direction. The Cousteau Society stands ready to continue to work with you and the Committee toward the goal of enhanced conservation of coral reef ecosystems. As a start, I have attached a series of recommendations compiled by the Cousteau Society intended to highlight opportunities for enhanced conservation for coral reefs, and in particular, recommendations for specific scientific research.

Thank you.